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SUBJECT Spacebridge to Moscow

ANNOUNCER: Moscow, September 25th, 1984. Scientific American magazine holds its annual meeting here in the Soviet capital. In an era of strained East-West relations, collaboration between Soviet and American scientists is severely limited. But today official Soviet television, Gostela (?) Radio, and the PBS science series Nova will hold a satellite teleconference, a space bridge, as the Russians call it, between eminent American and Soviet scientists.

Moderator Sergei Kapitza is editor-in-chief of Scientific American's Russian edition and host of a popular science show. This teleconference is expected to be broadcast to an estimated 100 million Soviet viewers, as well as millions of Americans.

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MARVIN GOLDBERGER: Welcome. I'm Marvin Goldberger, physicist and President of the California Institute of Technology. You're about to be part of a major international event, seven leading scientists, three Soviet and four American, meeting face-to-face via satellite to share results of their latest research.

The first topic is controlled thermonuclear fusion, a potentially limitless, but still inaccessible, source of energy.

ANNOUNCER: Fusion powers the sun. Deep in the core of this star, at temperatures of many millions of degrees, hydrogen nuclei smash into each other with such force that they fuse together, releasing enormous energy. For 30 years, Soviet and American scientists have been building experimental machines, trying to recreate on Earth the power that lights up the heavens. The problem: How to contain the hydrogen plasma, the gas heated to 100 million degrees, hot enough to vaporize the reactor walls?

In the early 1950s, in a major breakthrough, Soviet scientists invented the tokomak, a donut-shaped reactor encircled by powerful electromagnets. The magnets squeezed the plasma together, keeping the hot gas away from the reactor walls and repeatedly forcing the nuclei to keep crashing into each other until they fuse.

In principle, tokomaks can work. But in practice, progress has been frustratingly slow. Scientists in the United States and Europe have refined the Russian design and now operate the world's largest tokomaks. They have been able to get some real fusion going, but so far they're pumping a lot more power into the plasma than they are getting out.

Commercially useful fusion is still decades away, and we continue to burn energy at an alarming rate, squandering our precious fossil fuels. But we could find ourselves in a very different world where they hydrogen in sea water provides energy that is clean, cheap, and without limit.

Two of the teleconference participants, Roald Sagdeyev and Harold Furth, have devoted much of their lives to this quest.

[Remarks of Soviet scientists are translated]

ROALD SAGDEYEV: First of all, let me say that I'm very happy to be having a conversation with Harold, because one of the first articles on the theory of thermonuclear systems was done together with him. This would have been about 20 years ago, as I recall, or something along tyhose lines. So I would like now to get into the concrete subject now.

Among the major tokomaks which are being constructed in the world, one of the major ones is in Harold's institute. And I would like to know what new thing is being done in Princeton now.

HAROLD FURTH: Well, let me say, first of all, I think it's a great thing to be working with the Soviet Union on fusion. A hundred years from now the world will be very pleased to have a new energy source that can run on water rather than worrying about how to split up what's left of the oil and petroleum. And at the moment, it's a very good start that we work together and help each other.

Technically, the contributions of the Soviet side have been superb, including the personal contributions of Roald Sagdeyev before he went off into space.

I would say that at this point the basic physical understanding of plasmas is the absolute key to the situation. Our intention is not simply to produce burning plasma, at last; our intention is to produce practical fusion power. And in order to discover how best to do this, first of all one must understand the physics. And with the grasp of the physics, one can simplify the engineering and one can solve the economic problems. That's the right sequence, not the other way around.

SERGEI KAPITZA: You can't go too fast.

FURTH: That is right. It is going to take a while. At the same time, the real energy crisis isn't really going to hit the world until the middle of the next century. The important thing is to be ready when the crisis hits so that there will be a future for mankind. And that is a common problem that we have.

SAGDEYEV: There's another aspect which could perhaps be mentioned. A lot depends upon the sort of materials which these reactors are made from. You can create plasma. It can be shown to be in existence for a very short period of time. But how can the machine be made so that it works for a long period of time?

Only quite recently the very largest -- the newest generation of very large tokomaks have enabled these engineers to start this very important stage of the engineering research in these reactors.

Harold, I suggest that it will take several generations of these large tokomaks before we will have the necessary experience and know the proper combination of materials for the wall, for instance, which will have to be adjacent to the hot plasma, and the materials also for the use in the magnets, for cooling the magnets. There's a whole series of engineering problems, and these are now coming to the forefront.

KAPITZA: What do you think about that, Harold?

FURTH: I think exactly the same. It is going to require a number of steps. It will take decades. The situation is that we must be patient, we must work hard, we must work together, and then in the next century the payoff will come.

I think that once we have the burning plasma, once we can convince practical engineers that here is a real power source, then those problmes will be solved, and we will march on and indeed make power from water.

KAPITZA: And when will this be?

inspire practical people to build next-generation reactors, so that perhaps by 2010 there will be reasonable prototypes.

And as you know, the electrical utility industry is not a very fast-moving business. So I think it will be in the 2020s that the practical benefit will begin to be seen.

KAPITZA: And what do you think about this [unintelligible]?

SAGDEYEV: I think that the demonstration of an operation of a prototype should take place either at the end of this century or in the beginning of the next. And then there will be a struggle to improve the efficiency, cost efficiency, cost effectiveness, its ability to compete with other modes of energy production. And then it will come into use when it's necessary for humanity.

Now I have a question for Harold a about our old thermonuclear code.

How about bananas? Do you have bananas today?

FURTH: Yes. As they say in my country, yes, we have bananas.

Bananas are banana-shaped -- I thought everyone naturally would know. But bananas are banana-shaped orbits of charged particles in the magnetic field of the tokomak. And Roald and I, back in the old Siberian days, used to work on that. And the details of that are very important for predicting just how well the heat will be confined in a fusion reactor, and therefore how big it has to be.

So there is an example of how very fundamental science plays an absolutely crucial role in determining the engineering and the economics of fusion power.

KAPITZA: But now if the participants on the American and the Soviet side have no further questions on plasma, let us go on to the next question, of biology.

ANNOUNCER: Water, air, carbon, minerals. That's all it takes to make this and this and these, a few simple elements and the wonderful microscopic manual DNA. Every living cell contains this twisted double helix. Within the arrangement of its four simple compounds (adenine, guanine, cytosine, thymine) are encoded the genetic instructions for all life on Earth. It is the order and arrangement of these compounds, known by the letters A, G, C and T, that makes the DNA in the genes of one organism different from any other. DNA is a chemical statement of the unique identity of every living thing.

Even the simplest type of virus, basically just a strand of DNA surrounded by protein, has a unique DNA sequence, an order of letters that is identifiable and absolutely its own.

Within an organism, every cell has the same DNA, the same genetic material. Why, then, do some cells of a tree become leaves and others the trunk; in a baby, some cells develop into eyes, others hair?

Biologists have begun to understand not only how DNA sequencing works, but how the information within DNA is expressed as the characteristics of a living organism. By sequencing the DNA molecule and beginning to unravel the mystery of gene expression, these scientists may be close to understanding the nature of life itself.

Yuriy Ovchinnikhov and Alexander Rich are on the cutting edge of this effort.

ALEXANDER RICH: During the last 30 years or so, biology has undergone a quiet revolution. That is, we are beginning to define the molecular basis of living systems. This work has gone on in all of the countries, but it hase gone on in a vigorous way in both the United States and the Soviet Union.

The central issue in this, in biology is the -- rests with the DNA molecule. This is the molecule that contains all the genetic information of the cell, and it represents a profound mystery. It contains the directions for assembling the cells, and indeed the entire organism, and the directions for regulating the expression of various genes.

Now, at the present time we have a great deal of activity carried on in both the United States and the Soviet Union on the organization of DNA. For example, we're very much interested in the way DNA is organized in the nucleus of cells. We are very interested in the whole question of the relationship between the individual units or the letters that make up DNA. DNA, as you know, is made up of four different molecules. They're analogous to four different letters. And there is a very long message in the DNA molecule. The message has some relationship to the form of the molecule.

Recent work carried out in our laboratory and others has showed that DNA can not only form a right-handed molecule, so-called VDNA, but it can also form a left-handed molecule, so-called ZDNA. The particular form of the molecule depends very much on the sequence of letters or units in the molecule and the way that it's twisted. The right-handed VDNA is the stable form of the molecule. The left-handed ZDNA is a higher-energy form.

Now, in order to get an understanding of how the form of the molecule is related to the expression of genes, what we really need to do is learn more about the sequence of letters, so to speak, in the molecule.

Now, there has been a great deal of work done recently on DNA sequencing. For example, recently a group in England sequenced a virus which has 175,000 letters in it, a rather large number.

One of the projects that I think would be excellent for an extension of U.S.-Soviet collaboration would be to join jointly in an effort of sequencing, for example, the entire gene, the genome of the baterial -- of the colon bacteria that is used commonly in biological systems. That bacteria has four million letters in it. If, for example, we could determine this sequence, it could be -- we could write the entire sequence out in a book of about a thousand pages. That would be the book of E. coli. Having that information would teach us a great deal about how that organism lives. I think we could do this by the year 1990.

If we went one step further and looked at a common fruit fly that is used for biological research, that genome contains seven of these booms E. coli-sized. If we have that information, we would then be able to learn something about the manner in which that organism develops -- that is, the developmental biology, how you develop legs, an abodomen, and head, and so on. All of that information is encoded in there in a way that we don't understand.

Ultimately, we might even go on to the human, where there would be 800 books E. coli-sized in the entire genome of the human. Knowledge of that, we might, with a good effort, good joint effort, be able to achieve that by the year 2000. And with that we would have the basic information for learning something which would be of great value in understanding a variety of genetic diseases, developmental problems in humans. It would be of great practical value. And I think a program like that would be a very exciting one.

YURIY OVCHINNIKHOV: First of all, I would like to say how happy I am to see Alex here. We quite recently had a meeting in Moscow, and I see that he's gotten tanned. I see that he got a good rest over the summer. Generally - it was generally more difficult to talk to him by telephone that it has been today through the space link.

Now, as concerns our work as biologists, indeed I certainly agree with what Professor Rich said, that it's necessary now to know this language, inasmuch as the ability to know his language would enable us, in a guided way, to ascertain the genetic apparatus of any living being, including up to the human.

Now, the problem of reading the genetic apparatus, the genome of a microorganism such as the E. coli, I think, is one of the years to come, and in the near future. And as far as the human is concerned, if we had this, if we knew this about the human, it would help us very much to learn about cancer and inherited disease, congenital diseases. For the time being, we cannot resolve the problem of cancer and cancerous illnesses. But this information is obviously written in the human somewhere, and we have to be able to find it. Thus, we would be able to stop cells from developing in an undesired direction by acting on its genetic content.

And obviously, if we knew about this genetic apparatus of the human, using the efforts of the scientists of our two countries, I think that this problem would be a realistic one and we could solve it realistically somewhere about the beginning of the next century. Indeed, this would have very serious significance. And if we were to make use of contemporary computers to analyze this problem, this would also help us to solve a number of practical questions involved with health care, and agriculture as well.

So I want to conclude our biological study with the following comment. As an intermediate stage, it might be better to look at some -- the genome of some plant, because plants are simpler than a human organism, and this might help us to resolve some of the food problems of the world if we could learn more about one of -- some green plant. This could be done by our combined efforts, and this undoubtedly would lead to a major contribution.

KAPITZA: Now I would like to go on to the next theme, which is cooperation in the study of the Earth.

ANNOUNCER: Planet Earth, 4.6 billion years old and not yet finished. It's still shuddering beneath the surface and erupting in periodic volcanic explosions and violent and destructive earthquakes.

Movement happens along the boundaries of so-called plates, of which the entire surface of the Earth is made, great chunks of land which have been arranging and rearranging themselves since the world began. This constant and massive activity buckles the thin crust of the planet in recognizable patterns which have become well known to seismologists.

International cooperation among American and Soviet seismologists has increased our understanding of what happens in those earthquake zones. There is now great promise for actually predicting earthquakes and avoiding the loss of human life, if not the destruction of property.

Hidden beneath the Earth's surface, another kind of destruction goes on, underground testing of nuclear weapons. Seismographic instruments are now sensitive enough to detect even relatively small nuclear explosions. Their signatures are clear, recognizable, and distinctively different from those of earthquakes.

With improved cooperation between their governments, seismologists are confident their science could assure verification of a comprehensive nuclear test ban treaty.

Vladimir Keilis-Borok and Lynn Sykes have each spent more than 20 years working on these problems.

LYNN SYKES: It's important to realize that many countries of the world have a serious earthquake problem. For example, already in the 20th Century more than a million people have been killed by earthquakes. There are sizable areas of both of our two countries that are earthquake-prone and have had a long history of earthquakes.

Valodia, you've been working on the problem of global earthquake risk. Could you tell us a little bit about that?

VLADIMIR KEILIS-BOROK: Yes. I think that my news is bad. Seismic reisk for the major cities of the world is growing. And with the population explosion in the cities, by the year 2000 between 20 and 60 million people will be in somes of catastrophic earthquake danger, even if only in the large cities. this is because they simply live in those places. They're not causing the earthquake themselves. It's just that they happen to live in earthquake zones.

Recently we were at an international conference and we talked about suicidally inclined cities, or city suicides. In the next 10 or 15 years, eathquakes, I think, will start to be the same kind of problem for humanity which the black plague or the black death was in the Middle Ages.

Of course, we have no reason to feel ourselves helpless in this connection, nor thinking blue. There is a lot that can be done. In particular -- this would be inadequate, but it's still necessary -- to improve our own abilit to predict earthquakes.

Lynn, you have been very much involved in global monitoring of one of the earthquake zones. Now, on the question of the seismic gap, do you think that this sort of monitoring will help the large cities and the populations of these large cities?

SYKES: I think there's no question about that, that several large cities are located near some of the major earthquake zones of the world. For example, we now realize that most of the world's earthquakes occur in rather narrow zones that are at the boundaries of the very large plates that make up the surface of the Earth. However, what happens there is that these plates are not moving continuously. There's a rather large amount of friction at the boundaries, and pressures build up to the point in which about every 100 years there is movement and a very large earthquake.

What we've recognized is that most of the world's large earthquakes have occurred in those places that have not had large earthquakes for a long time. So we've been able to single some of those out.

One of the major plate boundaries passes from the San Andreas Fault of California through Alaska, Kamchatka, to Japan. So we've been able to pick out some areas there that for the next 10 or 20 years look like they have a more likely chance of having large earthquakes.

One thing that our two countries have been working on, and other countries in the world, is the problem of earthquake prediction. For example, we've had a joint program between the United States and the Soviet Union for about the last 10 years.

Valodia, what do you think are some of the major recent advances in earthquake prediction?

KEILIS-BOROK: I think that this was extremely successful cooperation. We exchange material, know-how, technology, and ideas. And the principal result was that we started to understand some properties of the earthquake process itself. We have learned how to recognize the areas which are most dangerous, from the point of view of earthquakes, where they can arise. This required the integration of geological and geophysical data and integration of concepts. And we found certain areas, and among them we found some where it was being planned to construct nuclear power stations.

And many thought, and we of course agreed, that the ability to predict earthquakes is still a little bit unclear and imprecise. In order to imporve it, we have to study some of the fundamental problems of the movement of material in the Earth. We need some models of the construction of the interior of the Earth. I think this would be the area of future progress. This is a problem which is very substantial.

KAPITZA: Now, a second one which I wanted to direct attention to is connected with the fact that seismic observations are connected with the possibility of verifying nuclear tests underground. And we would like to know what the earthquake science can contribute to this. We'd like to ask both Professor Sykes and Professor Keilis-Borok, who were advisers of our two governments in this connection.

SYKES: Yes. I think it's important to realize that seismology has made a major contribution in this area of verification of a treaty that would ban all atomic testing. It's of course important to remember that such a treaty still does not exist. The arms race has continued underground since 1963.

Seismology is the main tool for identifying that underground atomic tests have taken place. A very important aspect there has been to differentiate the signals of earthquakes from those of underground tests. And there, Valodia, made one of the early major contributions. That was in indicating that there would be a very large difference in the frequency content of waves from earthquakes compared to those from explosions.

Where do you think this subject now stands?

KEILIS-BOROK: I'm afraid that it has gone -- not only gone beyond the area of fundamental research, but even beyond the area of scientific research generally. Let me take the words of Roosevelt: There's nothing to be afraid of but fear itself.

If we take the difference in the spectra of surface waves and the structure of the seismograms, and you study the possibility of the physical sources of these waves, there's no reason to object to the possibility of an effective system. A system involving 11 stations around the world would be definitely effective.

What I see now is simply a bottomless pit of absurd concerns. Scientists could certainly play a role here to prevent further polarization of this issue.

Progress, thus, in the area of science is moving along much faster than progress in the area of negotiations. The question of hampering the arms race, the nuclear armament is very important, and this would be a major contribution to this.

I can say, myself, that for scientists the question of instrumental verification is quite a different matter than -- for scientists than for non-scientists. We verify one another not because we don't have confidence in one another, but because we want to see science move forward. That is our own approach to this very important issue. And it's a very important matter which we have to bear in mind in any discussion of verification.

KAPITZA: Let us now go on to the next theme of our discussion, which is what we can say about outer space and promising areas and avenues in connection with space research.

ANNOUNCER: 1975. The Apollo-Soyuz mission provided millions of earthbound viewers with some of the most tangible images of joint Soviet-American space research. For decades, physicists and astronomers from the two nations have also been joined in asking fundamental questions concerning the origins of our universe. In search of answers, scientists have probed the deep reaches of space with powerful and precise instruments. They discovered a sky full of invisible radiation, X-rays, ultraviolet rays, and radio waves. These signals revealed that the present-day universe is expanding outwards, uniformly and in all directions. By extrapolating that motion backwards, astronomers estimate that the expansion began in a cosmic big bang some 18 billion years ago.

Crucial confirmation of their theory came in 1968 when two American scientists detected a nearly uniform radio signal filling the universe. Known as three-degree radiation, this signal is the faint remnant of the energy of the extremely hot, tremendously compressed early universe.

Since the '60s, space physicists have worked to obtain ever-clearer maps of this radiation and to study the tiny gradations in the signal for clues to how the galaxies and stars were born.

Roald Sagdeyev and Philip Morrison have shared the grand excitement of this quest.

SAGDEYEV: Let me just say that research in space and astronomy is one of the oldest sciences. What is new is that the century of space research is on us now, and we now can do investigation of research in space by orbiting laboratories.

And I would like to ask Phil Morrision to tell us what he thinks about the significance of this step, from research of space on Earth to research of space in space.

PHILIP MORRISON: Well, I think it's clear that we live in a time -- we're lucky enough to live in a time, like the time of Galileo, when the naked eye, which was certainly the most powerful astronomical instrument for most of the life of our species, was augmented by the telescope. And nowadays, as you know, in the last generation, we've been able to go outside the atmosphere, in many different ways, and stay for a long time in space and get a good look at the world outside, which, of course, is the basis of astronomical studies; important because it tells us where the whole thing came from, and perhaps where it is going.

And I'm excited by the recent paper that you and your group sent us, Roald, which gives the first look at the invisible radiation in the millimeter band that we have seen for a long time, now and again from the ground, from balloons, from rockets, and now, for the first time, an all-sky map.

This radiation is the oldest radiation we know. It comes from the farthest distance that we shall probably ever see. It comes from gas behind, further away than any star or galaxy in all the work that we have done. It is, we believe pretty firmly, the relict (?), as you call the telescope, the relict of the Big Bang itself. And it's very exciting to see your satellite, just down, as I understand, just stopped its function, that has given us a six-month study of this from outside the atmosphere.

What did you see? What are the imperfections of this map? How different is it from the perfect symmetry that is too ideal to expect?

SAGDEYEV: The first glance at the map which was synthesized after eight months of observations and after the satellite, with stabilized rotation, used a small radio-telescope with about a 20-centimeter antenna, in fact will show you the map which we quite recently exchanged. It's a colored map showing the different temperatures, ignoring different galaxies and stars, but somehow looks at the sky on a very large-scale way and shows there is about six degrees difference in temperatures. And you will see that. Indeed, you see some temperature gradations quite clearly marked, and changes in temperature.

This was a dipole study and it comes from the fact that the solar system is moving at a speed which is left over from the Big Bang and it's moving at a very high speed, which eans that because of the Doppler effect, we get different temperature readings from different directions. And the difference is between about one-hundredth of a degree.

A great deal of work is going to have to be done to synthesize the data obtained from this satellite, the Prognos 7 satellite, and then use this artifact which is left over from the origin of the solar system and have a map which again is non-homogeneous in its temperatures, and we see a difference of about one-tenth of a degree Kelvin.

Those who are involved in cosmology, who are so thirsty for data about the earliest stages of the universe, would like to have higher accuracy than this. Then it would be possible to ascertain if there's some other configuration different from the dipolar one, some quadrapolar configuration. This is another issue to be investigated.

KAPITZA: It's a very good example how knowledge is always continuous and we always want to know more than we know already. We could continue and talk endlessly on this subject, but our time is short. And thus I would like to raise some general issues connected with international exchange of information and cooperation.

Now, if there are no questions or comments from Dr. Morrison -- have you any comments, Dr. Morrison?

MORRISON: Well, I would only like to say this: that if you look up at the sky this month, in autumn, toward the sun, you could imagine there are stars behind the sun. You can't see them, but they're there. We're moving, the sun and Earth and all, in this mighty motion that Roald just showed us on the map. That's the direction were all going with respect to the average matter in the whole universe, which is what gives us, we think, the major part of that [unintelligible] background.

So, look at the sun, think you're moving that way just now. Six months from now, it's behind you.

KAPITZA: Thanks. It's a good model and a good way to explain these things.

Now, in the time we have remaining to us, we want to talk about the prossibility of scientists contributing to the solution of broader problems, not only the narrow problems which we are particularly involved in.

RICH: I think it's useful to point out that the U.S. and the U.S.S.R. both have very large scientific establishments -- in fact, the largest in the world -- but their organization and strengths are different. That is, the thrusts, so to speak, of science in the two countries, while they have many similarities, they also have significant differences. And it is just on that issue, I think, that a very cogent argument can be made about the desirability of having international cooperation.

OVCHINNIKHOV: This is a very important issue, without any doubt, which my colleagues are mentioning. The general opinion of all scientists working in all areas of science is that science today can give humanity the opportunity for progress and for a happy life. But as far as the achievements of modern biology are concerned, one can state with confidence that biology today could solve the problem of providing food to everyone in the world.

What we have to relly answer is whether we can resolve the dangers which are of such concern to humanity. But to do this, to eliminate these dangers, we have to work together, we have to put together the enormous potential of each other's sciences. And we should raise our voices, we should perhaps be more active in behalf of the idea that war is not a way of solving problems among countries. Peaceful work, peaceful labor is the way that these problems should be solved.

Now, we know what these problems are and we feel very strongly that we have to resolve them. But there are a number of things going on in the world which are a source of very great anxiety for us, and our work in this area -- should be directed to this area, and our authority should be directed at helping to eliminate war from the life of the world today. It would be much easier and more agreeable for us then to get about solving the problems facing us, each in our own areas. And then our achievements will be a source of joy to humanity, both in our own countries and others.

I need only mention the problems of the developing countries today. And if our two countries, the two largest and scientifically most advanced and economically most advanced countries in the world, do not try to help the resolve the problems of the so-called Third World, then I think it will be hard for the Third World to solve these problems for themselves.

And thus, the contemporary task of science is to understand these problems and to set about solving them practically.

FURTH: Let me perhaps make a brief comment. I said earlier that 20 years ago, when we were strolling through the Siberian woods, we hoped that the good feeling and cooperation in science would radiate out and bring about collaboration in many fields. But as we all know, at present there are some very serious problems. And the danger is that some of the bad feeling from those problems is beginning to radiate in. So that when I appear on a program like this and say what a woonderful relation we have had, I feel a little guilty because I don't mention what the problems are.

But one can't solve difficult problems over the airwaves. And so I think the appropriate thing is to say, basically, we have a very sound, firm, friendly relation here. And what we need to do now is march forward, solve the problems, increase collaboration in fusion, in science overall. And heaven knows, it would be logical and rational and scientific if our nations then collaborated on a wide front. And it would be to the great benefit of mankind.

KAPITZA: Thank you.

There is one point that is worth maybe raising in the last minutes that are available. If we look correctly, science has got to expand the area of man's knowledge and man's grasp. And I want to introduce the concept of scientific humanism. And I would like the participants here to comment very briefly on this concept of scientific humanism.

RICH: I think that scientists have two responsibilities. They, of course, have a responsibility to understand nature and explain it to the other people. But they also have, I think, a speacial responsibility in just this area of ethical considerations. It is the humane application of knowledge which really differentiates our society from others. And we, I think, must in fact do our work with that fully in mind.

But let me then just close our meeting by simply sayiong to you [Russian expression]. Science and peace relly is the direction that we should all move towards.

[Asides about technical difficulties]

RICH: My feeling is that a meeting of this type is quite valuable. It's very important that we maintain this kind of collaborative interaction. It's a very stabilizing interaction and one which I think has positive consequences for both countries, in particular, and for the world as a whole.

MORRISON: Aren't the consequences really of two quite distinct kinds? One is what we are doing here, which is some way of making a public demonstration of the degree to which we have colleagues and necessary support from other countries, especially from the Russians, who are such a powerful science. But also, just as you said, the bricks of science are built in many places. They are a tremendous brickyard over there. And it's both a moral and a practical consideration that we should try to share what they're making, just as they surely have something to gain from us. And the less we are in touch, the less that can happen. Science doesn't live well in isolation.

SYKES: For example, in earthquake studies, this is an area where both the United States and the Soviet Union have gained a very great deal by our collaborative efforts. International exchange of data goes back probably 50 or 75 years on that subject. So, like meteorology, this is not something new. But, for example, my going to the central part of the Soviet Union and seeing an area that is quite different from the earthquake-prone areas in the United States was a very good experience. there are certain things that will be binders, for example, in studying earthquakes in California that we can see better in other countries. And likewise, I think Soviet investigators can take advantage that the San Andreas Fault in California is generally simpler than their areas. We have areas that are very similar, like Kamchatka and Alaska, in which there is a lot of room for interchange.

Perhaps one thing that impressed me today was that I tended to think that earthquake studies were one of the main areas where we had a very significant exchange that's benefited both countries. It's also a number of other areas that we've heard discussed here today. So, that was perhaps new news for me.

FURTH: Well, I was similarly surprised that it wasn't just fusion research in which there was such great collaboration; it even mixed in to things like seismology.

RICH: And there's the other very important issue brought about by the discussion of the nuclear test ban. The scientists are in agreement. The methodology at present is capable of detecting down to fairly low levels nuclear explosions. the political implications are quite clear. If we want to have a comprehensive test ban...

MORRISON: We could.

RICH: ...we could do it.

SKYES: Let me comment about that, because I, and I thing many of my other colleagues, the seismologists, believe that the main scientific problem related to verifying a test ban was solved about 1968. Instruments have been in place, and so we have had a lot of experience with monitoring in that area.

Clearly, we still don't have the test ban, and the problem is certainly overwhelmingly one of political will to go ahead and conclude negotiations towards a comprehensive test ban.

FURTH: To pick up this comment of Kapitza's about humanism and science. I think that shed some light on why we get along so well together. One of the questions this program is bound to raise is, you know, why do these guys get along so well together? And I think the answer is that truth-telling certainly is a very fundamental human value, and you can't last very long in good science without having a devotion to truth-telling. And that simple element, in spite of the geographical differences and the political differences, just makes great friends of us. It's a terrific thing. And somehow, it should be possible to build on that, it seems to me.

GOLDBERGER: With me this evening is Loren Graham, professor of history of science and an expert on Soviet science at MIT.

Could you give us some feeling for what the magnitude of the collaborative research activity has been over they years?

LOREN GRAHAM: Well, scientific exchanges between the two countries have been going on for a long time, almost 30 years. And they've never been entirely cut off. But they've had their ups and downs, and we're in a down.

The peak came in 1975, when there were about 2000 Soviet and American scientists going back and forth. This year, I would guess, no more than a hundred.

GOLDBERGER: What are some of the causes for this decrease in the exchange program?

GRAHAM: Partly because of government policy and the end of detente and the cooling of relations with the Soviet Union that everyone knows about. Partly because American scientists themselves have become unhappy with some aspects of the exchanges. The National Academy of Sciences, for example, cut off most of its collaborative work -- not its individual exchanges, but most of its collaborative work -- with the Soviets in January of 1980 shortly after Andrei Sakharov, the great Soviet physicist, was exiled to the city of Gorky. Many American scientists still feel very strongly on that issue.

And, in fact, I would have to say that if I wanted to add anything to the mood that we saw here at this wonderful event, it would have to be the somewhat sobering addition, additional comment that the American scientific community itself is fragmented on this.

GOLDBERGER: It was particularly unfortuante that, for example, Sakharov himself could not have been on such a program, because he was a major contributor, in fact continues to be a major contributor, in the area of controlled fusion, and also in cosmology, the origin of the universe.

I think it's important to try to understand why the international scientific community is os exercised about what has happened to Sakharov. We are a very intimate group. The fact that you and I are friends of the epople that appeared on this program is one example of that. And there is a spirit and an ethic of science, of freedom of expression, exchange of information, stimulation of ideas. And the fact that Sakharov, one of this close community of scientists, is no longer able to participate in this, I think, is an important factor in the attention that what has happened to him has been given.

GRAHAM: My own opinion is that the proper -- this is my personal view -- that the proper response to incidents like the Sakharov incident, repression, which definitely exists in Soviet science, the proper response is not to cut off exchanges, but rather to go. And while one is there, in addition to doing good scientific work, speak out one's mind on these issues.

This is not something that I would recommend as official policy, it's something that I just simply would recommend to individuals. When they go the the Soviet Union, be free individuals. And ask about science, work on science; and if something's worrying them politically, speak out on that too.

GOLDBERGER: I think it's important to emphasize something that was mentioned by Alex Rich and others about the value to us, not just to the Soviets, of an expanded exchange program. There are any number of areas in which the Soviets are absolutely first rate. And the misconception that this is a one-way street where they sit there benefiting enormously and we're performing some sort of missionary work is a complete misunderstanding.

GRAHAM: I think that's a message that the American people, by and large, have not received.

GOLDBERGER: I think that's true.

GRAHAM: I agree with you. There have been many studies of these exchanges, who gets what, who gets the most, what's the trade-off. The best of those studies have all come down to the conclusion that while the United States is probably, overall, in some rough sense, ahead of the Soviet Union in the sciences, there is still a great deal the United States can learn. There are many specific areas of science where the Soviets are at least equal with us. And therefore exchanges are a good thing. But I don't think that message is out.

GOLDBERGER: Loren, we've talked a good deal about the benefits to us of extended collaboration with Soviet scientists. How do they feel about the need for collaboration?

GRAHAM: The first thing that one has to notice is that for Soviet scientists, formal exchange programs are much more important than they are for American scientists. It's just about the -- a formal exchange program is just about the only way theat a Soviet scientist has to travel abroad. If you want to go to London or Paris next week, if you can satisfy the people at Cal Tech about leaving, you buy your ticket and you go. When a Soviet scientist wants to go to London or Paris or Pasadena, he or she can't just buy a ticket and go. They have to get in a formal exchange program.

So, these formal exchange programs are basically their only avenues of scientific contact. That's terribly important.

GOLDBERGER: From my own personal experience, I find it very rewarding to get to know the Soviet scientists whose papers I've read. I greet them by first names. I know their families. There is a personal strengthening of the bond which I thnik has a broad importance. And I think the greater the number of Americans and Soviet citizens that could visit each other and get to know each other, the better off we'd be. And I think that that's extremely important.

GRAHAM: I agree completely. That, in a sense, is the ultimate goal of such exchanges, that the kind of trust that is established through them can be extended to larger areas.

We wouldn't be realistic if we didn't notice that after 25 years of exchanges our successes there are modest.

GOLDBERGER: Correct.

GRAHAM: Modest. But they have happened.